

**DESIGN BASIS
GROUNDWATER PUMP AND TREAT TECHNOLOGY ANALYSIS AND
EVALUATION
PARKER LANDFILL**

1.0 PUMP AND TREAT TECHNOLOGY ASSESSMENT

The Record of Decision (ROD) issued for the Parker Landfill by the U.S. Environmental Protection Agency (EPA) in 1995 designated a groundwater extraction and treatment system (i.e., pump and treat system) for the purpose of treating impacted groundwater which exceeded Interim Groundwater Cleanup Levels (IGCLs) at the point of compliance. As part of the Alternative Technology Analysis and Evaluation, URS has further assessed this remedial action to more accurately reflect the likely system requirements and associated costs. The following sections summarize the ROD-specified treatment technologies and provide the design basis for Alternative 1A (the 110 gallons per minute [gpm] pump and treat system specified by the ROD) and for Alternative 1C (the ROD remedy expanded to include downgradient groundwater extraction and treatment operating at 170 gpm).

This assessment does not constitute a final design analysis but provides a basis for assessing the pump and treat remedial action alternative within the current remedial alternatives analysis and evaluation. All costs provided here-in are vendor estimates for off-the-shelf costs and do not include design, delivery, assembly, or supporting infrastructure costs.

1.1 COMPONENTS OF THE ROD REMEDY FOR PUMP AND TREAT

The conceptual design outlined in the Feasibility Study (ESE, 1994) specified the following treatment components for the groundwater pump and treat system; inorganic pretreatment using carbonate/hydroxide precipitation, and volatile organic compound (VOC) treatment using air stripping followed by granular activated carbon. The specific technologies and the associated sequencing of the treatment train were to be further evaluated as part of the remedial design process. According to the Feasibility Study, for the 110 gpm source area groundwater extraction and treatment system it was assumed that 14.4 lbs/day of liquid-phase granular activated carbon (LGAC), 11 lbs/day vapor-

phase granular activated carbon (VGAC), and 4,910 gallons/day of raw sludge (2,340 lbs/day dewatered sludge [35-percent solids]) would be generated during operation.

Using groundwater chemistry data from the LTMP and modeled pumping rates for proposed extraction wells, URS has re-evaluated the carbon consumption rates, sludge generation rates, as well as metal influent rates as part of this current assessment.

1.2 TREATMENT OF VOCS

As indicated above, the ROD specified that VOC treatment was to be accomplished using an air stripper followed by LGAC and VGAC. Air stripping would provide substantial reductions in liquid-phase VOCs as the strippable VOCs are transferred to the vapor phase. Following air stripping, LGAC would treat non-strippable VOCs and SVOCs. Vapor-phase granular activated carbon would treat VOCs from the vapor phase.

VAPOR-PHASE VOC TREATMENT TECHNOLOGIES

Based on these treatment processes, and using groundwater influent chemistry as described in Section 2.0 and Section 3.0, vapor phase carbon isotherms were used to estimate VGAC usage based upon pounds of VOCs emitted per day. As described in Section 2.2, based on groundwater chemistry data obtained during RI and LTMP implementation, approximately 200 lbs/day VGAC would be consumed by the 110 gpm system (approximately 300 lbs/day VGAC would be consumed by the 170 gpm system as outlined in Section 3.2). Using the estimated VGAC daily consumption rates for each strippable contaminant, the design basis assumes that the strippable unsaturated compounds (alkenes) such as trichloroethene and dichloroethene, and vinyl chloride, would consume approximately 90-percent of the total VGAC quantity expended. Alkanes and methylene chloride would consume the remaining 10-percent of the VGAC.

Because of limitations to the VGAC technology in meeting air emission standards for influent compounds such as vinyl chloride, and due to the high operating costs associated with these VGAC consumption rates, alternative emission controls were assessed to

determine if there were technologies which could reduce the VGAC consumption rate and address vinyl chloride. Both steam regenerable VGAC systems and thermal oxidation systems were considered.

Factors and conditions pertaining to steam regenerable VGAC systems are as follows:

- URS contacted four vendors who have manufactured steam regenerable VGAC systems. Of these vendors, only one (Vara Calgon Carbon) was actively marketing these systems currently.
- The systems require a source of potable water for boiler feed water.
- Steam carbon regeneration systems require non-contact cooling water to condense steam and VOCs. Based upon experience at other sites, approximately 50 to 60 gpm of non-contact cooling water would be required to condense the VOCs and steam resulting from regeneration of a carbon bed.
- The regeneration technology would not improve the ability of VGAC to treat vinyl chloride.
- Non-contact cooling water would have to be discharged to the Passumpsic River.
- Assuming two 1,000-pound VGAC canisters are used on site, approximately 60 gallons of VOC-contaminated steam condensate would be generated per canister every 3 days.
- Based on the declining number of vendors supporting this technology, equipment replacement and maintenance may be an issue in the future.
- Vara Calgon Carbon provided a budget cost of \$325,000 to install a steam regenerable VGAC system.

Factors and conditions pertaining to catalytic or thermal oxidation systems are as follows:

- According to several vendors, catalytic oxidation can be sensitive and require very frequent monitoring and adjustment during operation. Thermal oxidation was reported to be less sensitive to study area conditions and likely would be preferential relative to cost and maintenance.
- Several vendors indicated concerns with the oxidation technology being able to achieve the Vermont air emissions standards for certain compounds (e.g., vinyl chloride).
- Since the air emissions will consist primarily of chlorinated compounds, the system will most likely have to scrub the off-gases for acid gases (e.g., hydrochloric acid). The emissions from the thermal oxidizer must first be cooled prior to treating with an alkaline wet scrubber. Therefore, a quench tower must be installed in addition to a wet scrubber.

- A significant volume of non-contact cooling water will be required to operate the quench tower and will need to be cooled prior to discharge.
- Wet scrubber scrubbing liquid will have to be manifested off site as an additional waste residual requiring disposal.
- Two vendors provided a budget cost of approximately \$400,000 to provide a thermal oxidizer with a quench tower and acid gas scrubber.

Both of these alternative VGAC technologies have significant issues and significant associated costs. Additionally, vinyl chloride emissions remain problematic. As a result, additive aqueous-phase VOC treatment technologies that minimize or eliminate air emissions controls should be considered.

AQUEOUS-PHASE VOC TREATMENT TECHNOLOGIES

As previously discussed, the daily carbon consumption for VGAC following an air stripper would be high (i.e., approximately 200 pounds per day for the ROD system assuming proper adsorption conditions) and it is likely that certain compounds (e.g., vinyl chloride) could not be adequately treated to meet discharge criteria. Alternative emissions control systems also have their own disadvantages as discussed above.

Several alternative treatment technologies for aqueous-phase VOCs were considered which would reduce the VGAC utilization rates. These technologies included Ultraviolet (UV)/Oxidation and Ozone/Hydrogen Peroxide Oxidation. Each of these technologies is discussed below.

Ultraviolet/Oxidation

Several factors must be taken in account when considering UV/Oxidation.

- UV/Oxidation is effective for treatment of unsaturated double bond chlorinated compounds (e.g., alkenes) including trichloroethene and dichloroethene. Approximately 90-percent of the estimated 200 lbs/day of VGAC consumption was due to the presence of alkenes.
- UV/Oxidation is not particularly effective for treatment of saturated alkanes (e.g., dichloroethane, methylene chloride, 1,1,1-trichloroethane). Therefore, these compounds will have to be removed by other technologies (i.e., LGAC, air

stripping with VGAC emissions control). Calgon Carbon predicted 35-percent destruction for methylene chloride, 50-percent destruction for dichloroethane, and 20-percent destruction for 1,1,1-trichloroethane using the technology.

- Groundwater will have to be pretreated to remove iron, hardness, color, and suspended solids.
- There is only one identified vendor (i.e., Calgon Carbon) that could provide a UV/Oxidation system.
- Calgon Carbon's budget estimate (off-the-shelf) for a UV/Oxidation system is \$173,000.

Ozone/Hydrogen Peroxide Oxidation

Several factors must be taken into consideration when considering Ozone/Hydrogen Peroxide Oxidation.

- Similar to UV/Oxidation, Ozone/Hydrogen Peroxide is effective for the treatment of unsaturated double bond chlorinated compounds (e.g., alkenes) such as trichloroethene, dichloroethene but is not particularly effective for the saturated alkanes (e.g., dichloroethane, methylene chloride, 1,1,1-trichloroethane) or for acetone, methyl ethyl ketone, and methyl isobutyl ketone. Most of the original estimate for VGAC consumption (i.e., 90-percent) was due to the alkenes and vinyl chloride.
- Alkanes will have to be removed by LGAC or by air stripping with VGAC emissions control.
- The Ozone/Hydrogen Peroxide system requires a 17 standard cubic feet per minute (scfm) acid fume scrubber.
- An ozone destruct unit is required.
- The system is relatively simple and critical equipment, such as ozone generators, could be replaced in the future as necessary.
- Groundwater influent will have to be pretreated to remove iron, hardness, color, and suspended solids.
- There is only one identified vendor (i.e., US Filter) that could provide an Ozone/Hydrogen Peroxide system.
- U.S. Filter's budget estimate (off-the-shelf) for a UV/Hydrogen Peroxide system is \$218,000.

Air Stripping

Vendors were contacted to obtain current technical information pertaining to air stripping units suitable for system application. Most vendors were proposing comparable systems similar to the NEEP shallow tray system, for which the off-the-shelf price was estimated at \$145,000.

Liquid-Phase Activated Carbon

Liquid-phase activated carbon will be installed after the air stripper to treat semivolatile compounds and serve as a buffer for any upsets occurring within the air stripper or changes to the organic loading rates. The LGAC consumption rate would be minimal with the incorporation of the UV/Oxidation technology.

The LGAC canisters will be sized primarily to provide a 15-minute contact time. Both Carbtrol and US Filter have recommended their 2,000 pound canisters. Each vendor's 2,000 pound LGAC canister is rated to treat up to 100 gpm and still maintain the appropriate contact time. Two 2,000 pound canisters will be piped in parallel and the flow divided equally between the two canisters to maintain flow through canisters at less than 100 gpm. Two additional 2,000 pound canisters will be retained on site in the event that break through is observed.

The liquid-phase activated carbon is not intended to treat acetone, methyl ethyl ketone or methyl isobutyl ketone. These compounds would likely be only scavenged during the oxidation process, are difficult to strip from the liquid phase, and have very low carbon retentivities. However, there are no water quality criteria standards or Safe Drinking Water Act standards for acetone, methyl ethyl ketone or methyl isobutyl ketone. Therefore, if a portion of these compounds are untreated by the system there should be minimal impact to discharge water quality.

1.3 TREATMENT OF METALS

Metals treatment would be in two phases and require two treatment technologies. Iron and hardness are present in significant quantities and require treatment prior to the air stripper. Cadmium, iron, lead, mercury, selenium, and thallium are present in concentrations that exceed water quality standards and must also be treated to meet the applicable surface water discharge criteria.

The groundwater hardness for the ROD system is estimated to be approximately 600 milligrams per liter (mg/l) as calcium carbonate. At these concentrations, calcium carbonate will precipitate as scale and foul air strippers, LGAC canisters, and related piping. The use of sequestering or dispersing agents to address iron and hardness would also act to bind other inorganics which have stringent discharge requirements (e.g., cadmium, lead), preventing them from being subsequently removed prior to discharge. Therefore, these technologies are not considered further and it is assumed that some softening will be required to reduce hardness to acceptable levels.

IRON AND HARDNESS REMOVAL

Iron and hardness will be addressed in the following manner:

- Groundwater will be collected in a 5,000-gallon flow equalization tank to equalize the differences in concentrations observed between the extraction well.
- A packaged treatment system consisting of a flash mix tank, a flocculator, and an inclined plate clarifier will be used. Hydrogen peroxide will be used to oxidize soluble ferrous iron to the insoluble Fe^{+3} state.
- The influent pH will be raised to a pH of approximately 9 to 10 (standard units) to precipitate calcium carbonate hardness along with Fe^{+3} iron and some manganese.
- A coagulant will also be added to the flash mixer. A flocculent or polymer will be added before the flocculation tank to agglomerate the coagulated iron and calcium hardness. The flocculated material will be allowed to settle out of solution in the inclined plate clarifier and will be collected in the sludge collection compartment or hopper.
- Sludge will be periodically removed from the sludge collection compartment via a timer and an air driven diaphragm pump and stored in a sludge collection tank. An operator will periodically remove sludge from the sludge collection compartment and dewater the sludge in a plate and frame filter press. The

dewatered sludge will be approximately 25-percent to 35-percent solids by weight and will be manifested offsite based on Toxicity Characteristic Leaching Procedure (TCLP) testing results.

- The clarified liquid will flow by gravity and then be pumped through sand filters for suspended solids removal. The pH of the filtrate will then be adjusted to a pH of approximately pH 7 (as determined by the requirements of the VOC treatment system).
- All equipment will be covered to minimize fugitive emissions and vented to the atmosphere. All equipment will be suitable for Class I, Division 2 environments due to the lower explosive limits (LEL) and upper explosive limits (UEL) of toluene and trichloroethene degradation compounds.

One vendor (i.e., Hydro-Flo) provided a budget cost (off-the-shelf) of \$242,500 for the coagulation and precipitation system with sludge handling system and polishing sand filters.

INORGANIC REMOVAL

As stated above, cadmium, iron, lead, mercury, selenium, and thallium are present in the system influent at concentrations that exceed water quality standards. The low water quality standards require treatment using technologies which can provide for near complete removal, such as reverse osmosis, ion exchange, or activated alumina.

Reverse Osmosis

A two-stage reverse osmosis filtration system would most likely be required to achieve the water quality criteria standards. Each reverse osmosis stage typically has a 15-percent solution rejection rate that must be recycled or treated and disposed of off site. Therefore, 15-percent of 110 gpm (or 16 gpm) will be rejected by the first stage. Assuming only 10-percent of the filtrate from the first stage will be rejected by the second stage, an additional 9 gpm will be rejected during the second stage. This is a total of approximately 25 gpm of rejected solution that will have to be recycled or treated.

Ion Exchange

As an alternative to reverse osmosis, ion exchange would also successfully remove inorganic compounds. Bench scale tests would have to be performed to identify the

proper resin type. The ion exchange system will be installed after the VOC treatment system to prevent VOCs from attacking the ion exchange resin. Strong cation/anion exchange resins with acid and caustic regeneration will likely be required since the weak cation/anion exchange sodium-based ion exchange resins may not be effective for the metal species present in the influent groundwater.

Contingent upon the results of the bench scale testing, additional pH adjustment might also be required. Vendors have been asked if the level of acetone, methyl ethyl ketone, and methyl isobutyl ketone are at concentrations that could affect the ion exchange resins since these compounds likely would not be completely removed by the VOC treatment system. To date vendors have not expressed any significant concerns.

The ion exchange resin will have to be regenerated periodically depending upon the loading rate. The regenerant solution will be collected in a storage tank (regenerant collection tank) for treatment and/or offsite disposal. The pH of the regenerant solution may be adjusted to precipitate as many of the inorganic compounds present as possible. The precipitated metals would be pumped to the sludge storage tank and combined with the sludge from the iron and hardness precipitation system prior to disposal.

The following options are available for the supernatant remaining in the regenerant collection tank.

- Recycled back to the Flow Equalization Tank,
- Manifested for off site for treatment and disposal, or
- Treated in an evaporator for volume reduction with the concentrate manifested off site.

Activated Alumina

Activated alumina is a potential alternative to ion exchange or reverse osmosis. Activated alumina can be effective for removing inorganic compounds. Activated alumina cannot be regenerated on site and must be disposed of off site. The effectiveness of this technology is contingent upon bench scale testing to assess the effectiveness for

removing the metals in the waste stream, the loading rates, the life expectancy of a canister, and the final cost to manifest the spent media off site based upon the metals and the size of the canister required. Based on flow rates, two pairs of activated alumina canisters would be piped in parallel and a total of 4 activated alumina canisters would be required, with the second pair of activated alumina canisters being piped in series following the lead canisters.

Inorganic Treatment Technology Comparison

Ion exchange has major advantages over both reverse osmosis and activated alumina. Reverse osmosis generates large quantities of rejected pass-through solution which would require additional treatment or would result in significant off-site disposal requirements. Ion exchange is more versatile than activated alumina and, once installed, the system may be significantly more cost effective to operate. Additionally, ion exchange resins can be blended to accommodate the metals present in the influent stream. Activated alumina cannot be modified appreciably.

Vendors for ion exchange equipment were reluctant to provide budget costs due to the limited information available. One vendor (NAPCO) provided a rough cost estimate of \$675,000 for an ion exchange system with regenerant treatment system.

2.0 ALTERNATIVE 1A: ROD-DESIGNATED PUMP AND TREAT SYSTEM FOR SOURCE AREA

2.1 GROUNDWATER CHEMISTRY

Influent VOC concentrations were estimated for the 110 gpm system based on the LTMP and RI groundwater data in conjunction with the modeled pumping rates. Using this data, estimations of the pounds per day of each compound of concern for each extraction well were made. From these influent sources, an average loading rate for the system was obtained for each compound.

VOLATILE ORGANIC COMPOUNDS

Assuming flow equalization, the estimated VOC concentrations of the influent for the 110 gpm system are as follows:

Trichloroethene:	0.9 mg/l
cis-1,2-Dichloroethene:	2.0 mg/l
Vinyl chloride:	0.06 mg/l
Tetrachloroethene:	0.02 mg/l
Toluene:	0.04 mg/l
Methylene chloride:	0.02 mg/l
1,1,1-Trichloroethane:	0.02 mg/l
1,1-Dichloroethane:	0.06 mg/l
1,2-Dichloropropane:	0.01 mg/l

Non-strippable compounds:

Acetone:	0.04 mg/l
Methyl ethyl ketone:	0.63 mg/l
Methyl isobutyl ketone:	0.03 mg/l

Vermont Water Quality Criteria (VT WQC) exist for the following:

Methylene chloride	0.0047 mg/l
Toluene	6.8 mg/l
Tetrachloroethene	0.0008 mg/l
Trichloroethene	0.0027 mg/l
Vinyl chloride	0.002 mg/l

There are no Vermont Water Quality Criteria Standards for the following VOCs:

1,2-Dichloropropane
Acetone
2-Butanone
1,1-Dichloroethane
cis-1,2-Dichloroethene
Methyl isobutyl ketone
1,1,1-Trichloroethane

The following VOCs do not have VT WQC but do have Safe Drinking Water Act Primary Standards (Maximum Contaminant Level [MCL], Maximum Contaminant Level Goal [MCLG], or Treatment Technique [TT]):

cis-1,2-Dichloroethene	0.07 mg/l MCLG	0.07 mg/l MCL or TT
1,1,1-Trichloroethane	0.20 mg/l MCLG	0.2 mg/l MCL or TT
1,2-Dichloropropane	0 mg/l MCLG	0.005 mg/l MCL or TT

Based on Section 1.0, treatment technologies for VOC removal include the following: air stripping, UV/Oxidation, and carbon treatment.

INORGANIC COMPOUNDS

Inorganic compound concentrations were estimated for the combined total influent flow by combining the total estimated pounds per day from each well and calculating the daily average concentration at a flow rate 110 gpm (0.16 millions gallons per day [MGD]). The total pounds per day were estimated using the average concentration of each inorganic compound in each well and the flow rate for that well.

The estimated inorganic compound concentrations for the combined flow indicate that the combined untreated groundwater would exceed VT WQC for cadmium, iron, lead, mercury, selenium and thallium. The following standards for cadmium and lead were calculated at 100 mg/l of hardness. Iron, mercury, selenium, and thallium have fixed standards not based upon hardness concentration.

- Cadmium: 0.0020 mg/l exceeds the Chronic limit of 0.0011 mg/l for Aquatic Biota

- Iron: 19.700 mg/l exceeds the Chronic limit of 1.000 mg/l for Aquatic Biota
- Lead: 0.0050 mg/l exceeds the Chronic limit of 0.0032 mg/l for Aquatic Biota
- Mercury: 0.000034 mg/l exceeds the Chronic Limit of 0.000012 mg/l for Aquatic Biota
- Selenium: 0.012 mg/l exceed the Chronic Limit of 0.005 mg/l for Aquatic Biota
- Thallium: 0.0040 mg/l exceeds the 0.0017 mg/l limit for Human Health Consumption of Water and Organism (Safe Drinking Water Act MCL is 0.002 mg/l)

The average estimated hardness for the receiving stream has been approximated to be 82.5 mg/l; therefore, the VT WQC may be slightly lower than these limits for cadmium and lead.

As discussed in Section 1.0, with exception of iron, these concentrations are too low to be treated by conventional metal treatment technologies, such as coagulation and precipitation or microfiltration, and additional treatment technologies, such as ion exchange are required to reduce these concentrations to levels below the water quality criteria.

HARDNESS

The estimated calcium concentration is 305 mg/l as calcium or 763 mg/l as calcium carbonate. This is classified as hard water that will scale piping, meters, air strippers, and LGAC canisters.

Hardness deposits (scale) can be prevented by removing the scale forming elements. Scale can also be prevented by adding a sequestering agent that will maintain the calcium and magnesium in solution. A deposit control agent might also be effective for preventing deposits from forming. A major disadvantage to a sequestering agent is that it will also chelate and bind other inorganic compounds in addition to the targeted calcium and magnesium. This could prevent these metals from being treated prior to discharge to the river. Therefore, a sequestering agent cannot be used for scale control unless the other inorganic compounds are removed first. Treatment technologies to remove

inorganics such as ion exchange or reverse osmosis are functionally limited in the presence of dissolved solvents (e.g., trichloroethene, dichloroethene). Therefore, solvents must be removed before the groundwater is treated using ion exchange. Since the equipment that will be used to remove solvents will be scaled and plugged at these hardness concentrations, hardness must be removed prior to VOC treatment.

IRON

The estimated influent iron concentration for the source area is 19.7 mg/l. This is equivalent to 26 dry pounds of iron (Fe^{+2} or Fe^{+3}) per day. Since precipitated iron will form $\text{Fe}(\text{OH})_3$ in water, approximately 50 dry pounds of $\text{Fe}(\text{OH})_3$ would be generated each day. This volume is too large to be removed by bag filters since a typical bag filter can only hold approximately 3 pounds of wet solids before it must be changed.

The magnitude of this volume of solids is typically removed via coagulation and precipitation using an inclined plate clarifier. Therefore, the treatment system will include a coagulation and precipitation system consisting of a flash mixer, a flocculation tank, and an inclined plate clarifier. Soluble (Fe^{+2}) iron will be oxidized to the insoluble (Fe^{+3}) state by adding hydrogen peroxide ahead of the flash mixer. Precipitated solids must be dewatered in a sludge filter and disposed of for offsite in accordance with federal, state, and local regulations.

MANGANESE

The estimated manganese concentration is 0.471 mg/l. There are no water quality criteria for manganese and no primary standards under the Safe Drinking Water Act.

Manganese is very soluble and does not precipitate appreciably at a pH less than 10.0. Therefore, manganese deposition can be mitigated by maintaining the pH below 8.0. It would be preferable to adjust the pH of the final effluent to a pH of approximately pH 7.5.

2.2 VAPOR-PHASE VOC TREATMENT

AIR EMISSIONS

The total estimated potential pounds emitted per day via air stripping for the combined wells operating at 110 gpm are as follows:

Compound	Groundwater Conc. (mg/l)	Air Emissions (lbs/day)
Trichloroethene:	0.90	1.19
cis-1,2-Dichloroethene:	2.0	2.74
Vinyl chloride:	0.06	0.08
Tetrachloroethene:	0.02	0.02
Toluene:	0.04	0.06
Methylene chloride:	0.02	0.03
1,1,1-Trichloroethane:	0.02	0.03
1,1-Dichloroethane:	0.06	0.07
1,2-Dichloropropane:	0.007	0.01

The potential Vermont air emissions limits are as follows:

Compound	Annual Average (micrograms per cubic meter) (ug/m ³)	Action Level (lbs/ 8 hr)
<i>Category I</i>		
1,2-Dichloropropane	0.01	0.00083
Methylene chloride	2.0	0.16
Tetrachloroethene	0.41	0.033
Trichloroethene	0.42	0.034
Vinyl chloride	0.20	0.016

Category II

None of the above contaminants were listed under Category II.

Category III

Contaminant	Annual Average (ug/m ³)	Action Level (lbs/ 8 hr)
Acetone	178,000	7,480
1,1-Dichloroethane	19,300	1,004
1,2-Dichloroethene	79,000	3,320
Methyl ethyl ketone	5,900	248
Methyl isobutyl ketone	490	25
Toluene	8,930	464
1,1,1-Trichloroethane	190,000	7,980

Acetone, methyl ethyl ketone, and methyl isobutyl ketone are considered non-strippable unless steam stripping is used.

No limits published for:

1,1-Dichloroethane
{Assume 95-percent removal required}

ESTIMATED VAPOR-PHASE ACTIVATED CARBON CONSUMPTION

Vapor phase carbon isotherms were used to estimate VGAC usage based upon pounds of VOCs emitted per day. Vapor-phase activated carbon design guidance requires that the relative humidity of the air stream be maintained at less than 50-percent. The calculations for the estimate of the daily carbon consumption assumed the relative humidity was less than 50-percent. Since the emissions from the air stripper will most likely be near saturation with respect to relative humidity, it was assumed that the air stripper air emissions would be heated to approximately 100 °F to lower the relative humidity from 95-percent down to less than 50-percent.

Calgon Carbon isotherms were used to estimate a daily VGAC consumption rate of approximately 200 lbs/day without the UV/Oxidation system in place. Calgon Carbon isotherms were used to estimate a daily VGAC consumption rate of approximately 20 lbs/day for the system with UV/Oxidation incorporated as a treatment process.

Based upon vendor recommendations, 3,000 pound VGAC canisters were selected. Surface loading rates of 50 to 75 feet per minute are recommended by typical design guidance for sizing VGAC. These 3,000 pound canisters are generally the only size VGAC canister that could provide a surface loading rate near this range. Assuming a 20 lb/day carbon consumption rate, the 3,000 pound canister would have to be changed every 150 days.

It should be noted that all carbon vendors were concerned about vinyl chloride due to the very low adsorptive capacity of VGAC for vinyl chloride. Methylene chloride was of equal concern.

2.3 LIQUID-PHASE VOC TREATMENT

Based on influent chemistry and Calgon Carbon isotherms, VOC removal using LGAC alone would result in a daily LGAC usage rate of approximately 1,000 pounds for the 110 gpm system. The consumption of LGAC would be significantly reduced using additional treatment technologies. For instance, if LGAC is installed following UV/Oxidation and the air stripper, the LGAC acts to only treat semivolatile compounds and serves as a backup measure to treat any upsets occurring within the air stripper (or fluctuations in organic loading rates), and LGAC consumption is minimal.

The LGAC is not intended to treat acetone, methyl ethyl ketone or methyl isobutyl ketone. These compounds have very low retentivities on LGAC. These compounds are also difficult to strip from the liquid phase. However, there are no water quality criteria standards or Safe Drinking Water Act standards for acetone, methyl ethyl ketone or methyl isobutyl ketone.

The LGAC canisters will be sized to provide a 15-minute contact time. Both Carbtrol and USFilter have recommended the use of 2,000 pound canisters. Each vendor's 2,000 pound LGAC canister is rated to treat up to 100 gpm and still maintain the appropriate contact time. Two 2,000 pound canisters will be piped in parallel and the flow divided

equally between the two canisters to maintain flow through canisters at less than 100 gpm. Two additional 2,000 pound canisters will be retained on site in the event that break-through is observed.

2.4 METALS TREATMENT

As discussed in Section 1.3.1, coagulation and precipitation would be the most feasible technology for removing the estimated 50 lbs/day of iron hydroxide generated from system operation at 110 gpm. Specialized treatment technologies would be required to achieve the microgram per liter discharge limits that would be required to achieve the VT WQC for some other inorganic compounds. Based on the information available (Section 1.0), ion exchange treatment has been selected as the preferred technology to treat heavy metals removal. Sludge generation is estimated to be 36 cubic feet per day.

2.5 PROPOSED 110 GPM SYSTEM COMPONENTS

The following is a summary of the 110 gpm treatment system.

The primary treatment train follows:

- 5,000 gallon flow equalization tank
- Hydrogen peroxide addition to oxidize soluble Fe^{+2} to the insoluble Fe^{+3} oxidation state
- Coagulation, flocculation, and precipitation with pH adjustment to pH 10 to precipitate iron and reduce calcium carbonate hardness to levels that would not scale treatment systems downstream
- pH adjustment to pH 7.0 to 7.5
- Sand filtration to polish the effluent from the inclined plate clarifier
- UV/Oxidation destruction of alkenes (trichloroethene, dichloroethene and vinyl chloride)
- Air stripping to remove alkanes (dichloroethane, trichloroethane, and methylene chloride)
- Bag filter polishing to protect the LGAC canisters from fouling
- LGAC

- Ion exchange trace metals polishing
- Final pH adjustment
- Passumpsic River discharge

Auxiliary and support treatment systems are as follows:

- VGAC emission control for air stripper emissions of dichloroethane, trichloroethane, and methylene chloride (with inline duct heater).
- Sludge collection and dewatering for the iron/calcium carbonate sludge generated by the coagulation and precipitation system.
- Ion Exchange regenerant treatment and disposal with an on site evaporator to concentrate liquids.

3.0 ALTERNATIVE 1C – PUMP AND TREAT FOR SOURCE AND DOWNGRADIENT AREAS

3.1 GROUNDWATER CHEMISTRY

The compounds of concern detected in the downgradient area are similar to those detected in the source area and incorporated into the 110 gpm system (Section 2.0). The anticipated treated groundwater discharge criteria and the air emissions limits that must be met for the 170 gpm system are the same as discussed for the 110 gpm system. Additionally, since the contaminants, treated effluent discharge limits, and emissions limits are comparable for the 110 and the 170 gpm systems, system assessment conducted in Section 1.0 is valid for the 170 gpm as well as the 110 gpm system.

Influent VOC concentrations were estimated for the 170 gpm system based on the LTMP and RI groundwater data in conjunction with the modeled pumping rates. Using this data, estimations of the pounds per day of each compound of concern for each extraction well were made. From these influent sources, an average loading rate for the system was obtained for each compound.

VOLATILE ORGANIC COMPOUNDS

Assuming flow equalization, the estimated VOC concentrations of the influent for the 170 gpm system are as follows:

Strippable	
Trichloroethene:	2.2 mg/l
Cis-1,2-Dichloroethene:	1.7 mg/l
Vinyl chloride:	0.08 mg/l
Tetrachloroethylene:	0.01 mg/l
Toluene:	0.03 mg/l
Methylene chloride:	0.02 mg/l
1,1,1-Trichloroethane:	0.01 mg/l
1,1-Dichloroethane:	0.05 mg/l
1,2-Dichloropropane:	0.01 mg/l

Non-strippable:

Acetone:	0.03 mg/l
Methyl ethyl ketone:	0.41 mg/l
Methyl isobutyl ketone:	0.02 mg/l

Vermont Water Quality Criteria exist for the following:

Methylene chloride	0.0047 mg/l
Toluene	6.800 mg/l
Tetrachloroethene	0.0008 mg/l
Trichloroethene	0.0027 mg/l
Vinyl chloride	0.002 mg/l

There are no Vermont Water Quality Criteria Standards for the following VOCs:

1,2-Dichloropropane
Acetone
Methyl ethyl ketone
1,1-Dichloroethane
cis-1, 2-Dichloroethene
Methyl isobutyl ketone
1,1,1-Trichloroethane

The following VOCs do not have VT WQC but do have Safe Drinking Water Act Primary Standards (MCL, MCLG, or TT):

cis-1,2 Dichloroethene	0.07 mg/l MCLG	0.07 mg/l MCL or TT
1,1,1-Trichloroethane	0.20 mg/l MCLG	0.2 mg/l MCL or TT
1,2-Dichloropropane	0 mg/l MCLG	0.005 mg/l MCL or TT

Based on Section 1.0, treatment technologies for VOC removal include the following: air stripping, UV/Oxidation, and activated carbon treatment.

INORGANIC COMPOUNDS

Inorganic compound concentrations were estimated for the combined total influent flow by combining the total estimated pounds per day from each well and calculating the daily average concentration at a flow rate of 170 gpm (0.24 MGD). The total pounds per day per well (source and downgradient areas) were estimated using the concentrations detected for each compound and the corresponding flow rate.

The estimated inorganic concentrations for the combined flow indicate that the combined untreated groundwater would exceed VT WQC for cadmium, iron, lead, mercury, thallium and selenium. The following standards for cadmium and lead were calculated at 100 mg/l of hardness. Iron, mercury, selenium, and thallium have fixed standards not based upon hardness concentration.

- Cadmium: 0.0015 mg/l exceeds the Chronic limit of 0.0011 mg/l for Aquatic Biota.
- Iron: 12.868 mg/l exceeds the Chronic limit of 1.000 mg/l for Aquatic Biota.
- Lead: 0.0057 mg/l exceeds the Chronic limit of 0.0032 mg/l for Aquatic Biota.
- Mercury: 0.000022 mg/l exceeds the Chronic Limit of 0.000012 mg/l for Aquatic Biota.
- Selenium: 0.0079 mg/l exceeds the Chronic Limit of 0.005 mg/l for Aquatic Biota.
- Thallium: 0.0023 mg/l exceeds the 0.0017 mg/l limit for Human Health Consumption of Water and Organism (Safe Drinking Water Act MCL is 0.002 mg/l).

The average estimated hardness for the receiving stream has been approximated to be 82.5 mg/l; therefore, the VT WQC may be slightly lower than these limits for cadmium and lead.

As discussed in Section 1.0, with exception of iron, these concentrations are too low to be treated by conventional metal treatment technologies such as coagulation and precipitation or microfiltration and more sophisticated treatment technologies, such as ion exchange, are required to reduce these concentrations below the water quality criteria.

HARDNESS

The estimated calcium concentration is 217 mg/l as calcium or 543 mg/l as calcium carbonate. The estimated magnesium concentration is 17 mg/l or 71 mg/l as calcium carbonate. Total hardness is, therefore, approximately 614 mg/l of total hardness as

calcium carbonate. This is classified as hard water that will deposit significant amounts of scale in equipment and piping.

As discussed previously, a sequestering agent could be used to chelate the calcium and magnesium to prevent deposition and scaling; however, the sequestering agent would also chelate other inorganic compounds making them difficult to treat to discharge limits prior to discharge.

IRON

The estimated iron concentration is 12.868 mg/l. This is equivalent to 26 dry pounds of iron (Fe^{+2} , Fe^{+3}) per day. Since precipitated iron will form $\text{Fe}(\text{OH})_3$ in water, approximately 50 dry pounds of $\text{Fe}(\text{OH})_3$ will be generated each day. This volume is too large to be removed by bag filters since a typical bag filter can only hold approximately 3 pounds of wet solids before it must be changed.

The magnitude of this volume of solids is typically removed via coagulation and precipitation using an inclined plate clarifier. Therefore, the treatment system will include a coagulation and precipitation system consisting of a flash mixer, a flocculation tank, and by inclined plate clarifier. Soluble (Fe^{+2}) iron will be oxidized to the insoluble (Fe^{+3}) state by adding hydrogen peroxide ahead of the flash mixer. Precipitated solids must be dewatered in a sludge filter and disposal of offsite in accordance with federal, state, and local regulations.

MANGANESE

The estimated manganese concentration is 0.3197 mg/l. There are no water quality criteria for manganese and no primary standards under the Safe Drinking Water Act.

Manganese is very soluble and does not precipitate appreciably at a pH less than 10.0. Therefore, manganese deposition can be mitigated by maintaining the pH below 8.0. It would be preferable to adjust the pH of the final effluent to a pH of approximately pH 7.5.

3.2 VAPOR-PHASE VOC TREATMENT

AIR EMISSIONS

The total estimated potential pounds emitted per day via air stripping for the combined wells operating at 170 gpm are as follows:

Compound	Groundwater Conc. (mg/l)	Air Emissions (lbs/day)
Trichloroethene:	2.2	4.49
cis-1,2-Dichloroethene:	1.7	3.39
Vinyl chloride:	0.08	0.16
Tetrachloroethene:	0.01	0.02
Toluene:	0.03	0.06
Methylene chloride:	0.02	0.03
1,1,1-Trichloroethane:	0.01	0.03
1,1-Dichloroethane:	0.04	0.07
1,2-Dichloropropane:	0.01	0.01

The potential Vermont air emissions limits are as follows:

Compound	Annual Average (ug/m ³)	Action Level (lbs/ 8 hr)
<i>Category I</i>		
1,2-Dichloropropane	0.01	0.00083
Methylene chloride	2.0	0.16
Tetrachloroethene	0.41	0.033
Trichloroethene	0.42	0.034
Vinyl chloride	0.20	0.016

Category II

None of the above contaminants were listed under Category II.

Category III

Contaminant	Annual Average (ug/m³)	Action Level (lbs/ 8 hr)
Acetone	178,000	7,480
1,1-Dichloroethane	19,300	1,004
1,2-Dichloroethene	79,000	3,320
Methyl ethyl ketone	5,900	248
Methyl isobutyl ketone	490	25
Toluene	8,930	464
1,1,1-Trichloroethane	190,000	7,980

Acetone, methyl ethyl ketone, and methyl isobutyl ketone are considered non strippable unless steam stripping is used.

No limits published for:

1,1-Dichloroethane
{Assume 95-percent removal required}

ESTIMATED VAPOR-PHASE ACTIVATED CARBON CONSUMPTION

Vapor phase carbon isotherms were used to estimate VGAC usage based upon pounds of VOCs emitted per day. Vapor-phase activated carbon design guidance requires that the relative humidity of the air stream be maintained at less than 50-percent. The calculations for the estimate of the daily carbon consumption assumed the relative humidity was less than 50-percent. Since the emissions from the air stripper will most likely be near saturation with respect to relative humidity, it was also assumed that the air stripper air emissions would require heating to approximately 100 °F to lower the relative humidity from 95-percent down to less than 50-percent.

Calgon Carbon isotherms were used to estimate a daily VGAC consumption rate of approximately 300 lbs/day without the UV/Oxidation system in place. Calgon Carbon isotherms were used to estimate a daily VGAC consumption rate of approximately 30 lbs/day for the system with UV/Oxidation incorporated into the treatment process.

Based upon vendor recommendations, 3,000 pound VGAC canisters were selected. Surface loading rates of 50 to 75 feet per minute are recommended by typical design guidance for sizing VGAC. These 3,000 pound canisters are generally the only size VGAC canister that could provide a surface loading rate near this range. Assuming a 30 lb/day carbon consumption rate, the 3,000 pound canister would have to be changed every 100 days.

3.3 LIQUID-PHASE VOC TREATMENT

As discussed in Section 1.2, LGAC will be installed after the UV/Oxidation and air stripper to treat semivolatile compounds and serve as a buffer for any upsets occurring within the air stripper or changes to the organic loading. Consumption would be minimal.

The LGAC is not intended to treat acetone, methyl ethyl ketone or methyl isobutyl ketone. These compounds have very low retentivities on LGAC and VGAC. These compounds are also difficult to strip from the liquid phase. However, there are no water quality criteria standards or Safe Drinking Water Act standards for acetone, methyl ethyl ketone or methyl isobutyl ketone.

The LGAC canisters will be sized to provide a 15-minute contact time. Both Carbtrol and USFilter have recommended the use of 2,000 pound canisters. Each vendor's 2,000 pound LGAC canister is rated to treat up to 100 gpm and still maintain the appropriate contact time. Two 2,000 pound canisters will be piped in parallel and the flow divided equally between the two canisters to maintain flow through canisters at less than 100 gpm. Two additional 2,000 pound canisters will be retained on site in the event that break-through is observed.

3.4 METALS TREATMENT

As discussed in Section 1.3.1, coagulation and precipitation would be the most feasible technology for removing the estimated 50 lbs/day of iron hydroxide generated from system operation at 170 gpm. Specialized treatment technologies would be required to achieve the microgram per liter level discharge limits for other inorganic compounds. Based on the information available (Section 1.0), ion exchange has been selected as the preferred technology to treat heavy metals removal. Sludge generation is estimated to be approximately 46 cubic feet per day.

3.5 PROPOSED 170 GPM SYSTEM COMPONENTS

The following is a summary of the 170 gpm treatment system

The primary treatment train follows:

- 5,000 gallon flow equalization tank
- Hydrogen peroxide addition to oxidize soluble Fe^{+2} to the insoluble Fe^{+3} oxidation state
- Coagulation, flocculation, and precipitation with pH adjustment to pH 10 to precipitate iron and reduce calcium carbonate hardness to levels that would not scale treatment systems down stream
- pH adjustment to pH 7.0 to 7.5
- Sand filtration to polish the effluent from the inclined plate clarifier
- UV/Oxidation Destruction of alkenes (trichloroethene, dichloroethene and vinyl chloride)
- Air stripping to remove alkanes (dichloroethane, trichloroethane, and methylene chloride)
- Bag filter Polishing to protect the LGAC canisters from fouling
- LGAC
- Ion exchange trace metals polishing
- Final pH adjustment
- Passumpsic River discharge

Auxiliary and support treatment systems are as follows:

- Vapor-phase activated carbon emissions control for air stripper emissions of dichloroethane, trichloroethane, and methylene chloride (with inline duct heater).
- Sludge collection and dewatering for the iron/calcium carbonate sludge generated by the coagulation and precipitation system.
- Ion Exchange regenerant treatment and disposal with an on site evaporator to concentrate liquids.